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Automatic Data Acquisition and Modeling of the Greifswalder Bodden Ecosystem

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With 2 Figures

Data acquisition

Data acquisition programs and equipment allowing high resolution in time and space are required to fully quantify changes in the parameters of ecosystems that are subject to rapid change owing to short generation times or patchiness.

Suitable measuring systems are being developed by the Department of Biology at Rostock as part of the ecological research program in the Greifswalder Bodden.

A modular platform with solar and wind energy supply systems has been in service since 1993 for measuring air and water temperatures, global irradiance, wind and currents (direction and velocity) and water conductivity. The data are measured at selectable intervals, and the stored data can be retrieved in different formats. Given the name ODAS, the platform is held on station by two anchored buoys and has so far been deployed four times in Greifswalder Bodden.

In summer, the probes must be cleaned weekly to remove algae. Ice cover in winter provides a natural reason for removing and testing the probes and analyzing the data. Another platform with probes, the Strelasund Measuring Mast, was put into operation in mid-1995. It carries a weather station for collecting meteorological data and an ECO memory probe for hydrological data. The bottom of the mast is hinged to permit the whole structure to be lowered onto the seabed during winter.

A synoptic measuring program using a towed fluorometer (Fig. 1) to make North-South and East-West transects through the bodden was started in 1994 and 1995. The fluorometer was mounted on a pontoon towed alongside the r/v "Gadus". Fluorescence measurements were taken at intervals of one second. Measurements, taken at wavelengths of 350 to 550 nm permit the chlorophyll *a* content of the water to be estimated. The addition of equipment for fluorescence measurements to the two stationary platforms is foreseen.

In the 1950s and 1960s, surface water currents established by following the drift of a current indicator by means of measuring equipment ashore. The same principle is still used today, but modern technology has been enlisted to improve its accuracy: the position of the indicator is now measured by DGPS and relayed back to the station (e.g. r/v "Gadus") by radio. The current speed and direction are then calculated from the continuous position updates. This data is recorded on nautical charts and used as input for our hydrological and ecological methods.

Mathematical modeling of the Greifswalder Bodden ecosystem with hydrodynamic aspects

The modeling of the Greifswalder Bodden ecosystem is based on an extensive series of long-term measurements as well as the data from the ODAS system. The data series include the following parameters:

- Salinity (SCHNESE 1962–65; WWD 1966–90; WESTPHAL 1981–95)
- Water temperature (SCHNESE 1962–65; WWD 1966–90; WESTPHAL 1981–95)
- Global radiation (Meteorol. Dienst d. DDR 1966–90; DWD 1990–94)
- Nutrients (SCHNESE 1962–65; WESTPHAL 1984–95)
- Zooplankton (SCHNESE 1963–65; BRENNING 1977–90; HÜBEL 1993–95)
- Phytoplankton (SCHNESE 1963–65; SCHMIDT 1972–81; KELL 1981–90; HÜBEL 1993–95)
- Microorganisms (SCHNESE 1963–65; WESTPHAL 1983–95)
- Chlorophyll *a* (SCHNESE 1963–65; WESTPHAL 1994–95)
- Seston (SCHNESE 1962–65; WWD 1966–90)
- Secci depth (SCHNESE 1962–65; WWD 1966–90; WESTPHAL 1981–95; HÜBEL 1993–95)
- Extinction (SCHNESE 1962–65)

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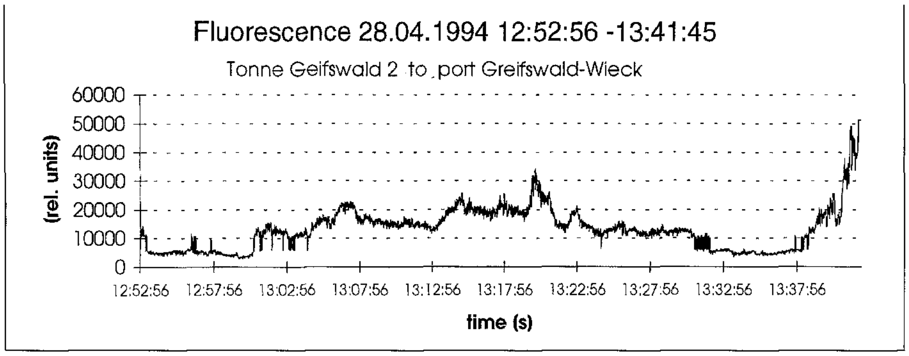

Fig. 1. Fluorescence measurement on a transect near port Greifswald.

At first, our models were programmed and tested on PCs using software developed in house. In 1995, E. EMBSEN (NIOZ) kindly gave us the program OpenSESAME 0.5 for UNIX computers which was designed specifically for modeling hydrological effects in aquatic ecosystems. The model is currently being transferred to the new system, and part of it is running on a Sun workstation.

The model

The latest version is based on an ecosystem model designed for the Darss-Zingst Bodden Chain by VIETINGHOFF (1982) and applied with suitable modifications to the Greifswalder Bodden system since 1987. It contains equations for pelagic and benthic communities. The pelagic compartment includes three phytoplankton groups (spring diatoms, green algae and cyanobacteria), a zooplankton group (copepods) and bacterial microorganisms. Equations are included for the nitrogen content of all groups and for soluble organics and inorganics in the water. The benthic part of the model contains ciliates and benthic bacteria. Detritus and detrital N concentrations are taken into account in both compartments.

Greifswald Bodden has been divided into four areas (boxes), all with the same coefficients, but with allowances to take into account the distributions of the measured biological and chemical parameters. The distributions within each box are assumed to be uniform (i.e. the boxes are well mixed). The forcing functions taken from our continuous measurements are salinity, water temperature and irradiance and the nutrients phosphorus and silicon. Nutrient inputs and population movements cannot be simulated with purely biological-chemical models. Hydrodynamic models can simulate nutrient transport, but only partly account for their biological transformation (uptake, mortality, sinking), which is important for the natural "self-cleaning" function of the system. The incorporation of both hydrodynamic and biological aspects into a single integrated model is complicated by the fact that the two models require different time integrals during processing. The hydrodynamic model requires a highly accurate spatial component with many discrete points, whereas the biological model calls for a realistic annual suc-

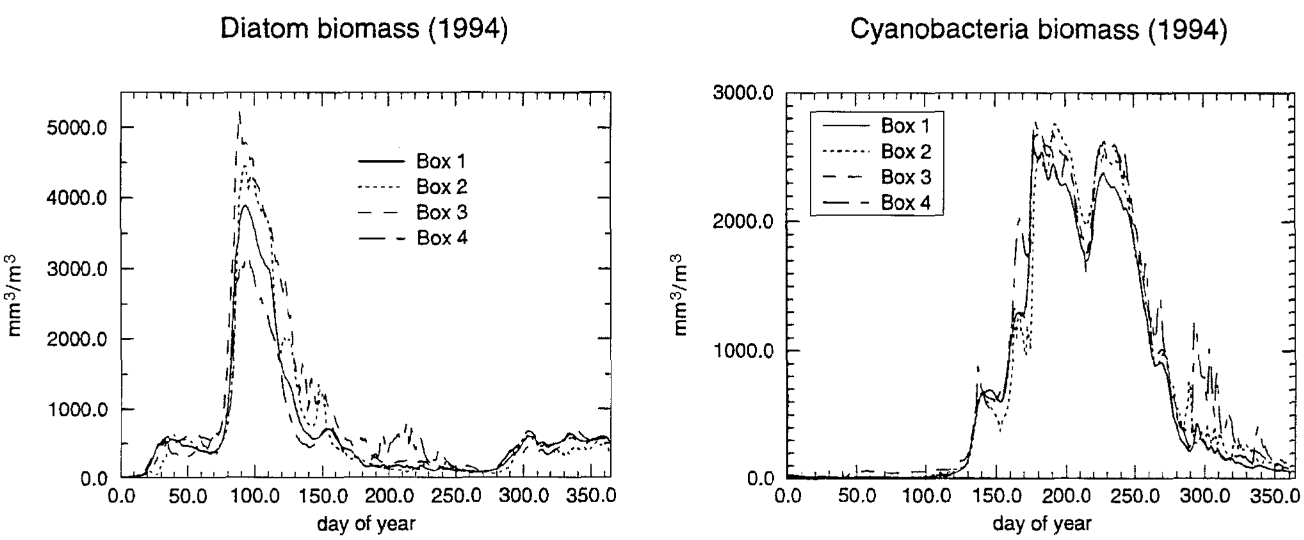

Fig. 2. Simulated seasonal cycle for two phytoplankton groups in the four boxes.

cession. The calculation capacity of our computers is inadequate to permit direct coupling of the two models.

Consequently, we have decided to use a simple off-line method to couple the biological-chemical model and the hydrodynamic model. Nitrogen inputs from adjacent shore areas are entered in relation to the corresponding hydrodynamic parameters. The data entered as forcing functions for each compartment are taken from those recorded at the corresponding measuring stations, so the variability in the modeled values is derived from that in the data series or from water transport. Modeled results and measured values are compared for evidence of significant relationships. The model results are compared with long-term data sets for, say, phytoplankton 1976–1981 (SCHMIDT 1990) in the case of the model without hydrodynamic coupling or with phytoplankton measurements in 1994 (HÜBEL et al. 1995) in the case of the coupled model.

The hydrodynamic variables in the model are based on the work of BUCKMANN (1998). Annual hydrodynamic variations for Greifswalder Bodden are calculated with a 2D or, for interesting scenarios, 3D model as part of the GOAP project. The experimental area is divided into compartments. The time series data we receive give the water transport per unit time across the boundaries of each compartment. The material and biomass contained in each water body is calculated by the biological-chemical model. The amount of material transported is added to the concentration in a box at each time point.

The complexity of the extensive data series with variable sampling times can only be fully interpreted by means of a mathematical-ecological model. Such models can be used for hypothesis testing and can stimulate new ideas and experiments, but are unfortunately overtaxed when used to examine some of the controversial topics currently under discussion. A model can never reproduce all aspects of a system, but presents only a limited view showing some of the most important relationships and dependencies.

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